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SIZE EFFECT ON FRACTURE TOUGHNESS OF GOLD THIN FILMS STUDIED BY BULGE TESTING

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A versatile bulge test setup was used to perform mechanical tests on rectangular gold membranes with thicknesses ranging from 100 nm to 350 nm. It can be used in a conventional way to calculate stress-strain curves and determine parameters such as residual stress and plane-strain modulus. Alternatively, the setup in Erlangen can be inserted into an atomic force microscope (AFM) which allows in-situ imaging of the topography of the deforming membrane.

In order to determine the fracture toughness K_{IC} of thin films, narrow crack-like slits of 10 μm length were milled into the center of the membranes by focused ion beam (FIB). Subsequently, the membranes were loaded until rupture. The investigated samples comprised freestanding gold films and films supported by a 100 nm thick silicon nitride film.

The fracture toughness obtained for every gold film is much lower than the literature value for bulk gold. However, there are two significant differences between supported and freestanding films. First of all, the supported ones exhibit slightly lower K_{IC} values. Secondly, their fracture toughness increases linearly with film thickness, whereas it remains constant for freestanding films. In-situ AFM scans of the crack tip region also reflect this difference in behavior. Supported films do not show any plastic deformation except directly at the crack tip. Failure occurs in a very brittle manner. In contrast, freestanding films exhibit widespread out-of-plane motion of grain clusters in front of the crack tip. Besides, stable crack propagation is observed before failure.

The new experimental results agree well with predictions from former models for the size dependence of fracture toughness.